A Whole-Forest Pulse-Label Study of Microbial Dynamics and Root Turnover

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RESEARCH OBJECTIVES

In the summer of 1999, there was a large atmospheric release of $^{14}CO_2$ near the Oak Ridge Reservation (ORR), Tennessee, from a local incinerator. The rapid photosynthetic uptake of the $^{14}CO_2$ created a pulse label for studying carbon (C) cycling through the ORR forests. Several institutions (four DOE labs, two UC campuses, the U.S. Forest Service, and a private firm) are utilizing this whole-ecosystem isotopic label to address unresolved issues in terrestrial carbon cycling. At Berkeley Lab, we are investigating (1) the longevity of fine roots, and (2) the pathways from leaf and root inputs to microbial biomass and soil organic matter. Here, we summarize the first year's results.

APPROACH

The ORR team used enriched and near-background leaf litter to create four treatments, depending on plant ^{14}C inputs: enriched roots, enriched leaf litter, both enriched leaves and roots, and no enrichment. We determined fine-root longevity by tracing the radiocarbon label through live and dead root populations. New root growth was isolated by harvesting roots that grew through a screen in the soil. For fungal dynamics, ectomycorrhizae were hand-picked from freshly harvested roots. For microbial biomass, chloroform fumigation-extracts of soils were freeze-dried and combusted for graphitization. Radiocarbon content was measured at Lawrence Livermore National Laboratory by accelerator mass spectrometry.

ACCOMPLISHMENTS AND SIGNIFICANCE

New root growth contains about 10–20% of the ^{14}C signature from the previous year's growth (Figure 1), showing that roots grow from a mixture of recent photosynthate and C storage from the previous year. This result is helping us parameterize root models and estimate fine-root turnover based on atmospheric trends in $^{14}CO_2$. Our data from this and other forests show no correlation in root lifetimes between different root-diameter size classes; we believe that the diameter-lifetime correlation observed by minirhizotron studies may only be valid for roots living less than 1 year.

The only plots in which ectomycorrhizal fungi were ^{14}C-enriched were those with trees that had enriched roots. This shows that the fungi were not receiving carbon from decomposition of organic matter, but rather from the live roots they colonized.

Microbial biomass was enriched in all treatments and depths. The rapid enrichment (~500‰ in 2002) is consistent with conceptual models of microbes as an active carbon pool that decomposes roots, litter, and dissolved organic material. The similarity to heterotrophic respiration values (~400–600‰) suggests that we may be able to use microbial biomass ^{14}C to estimate the season-integrated signature soil-respired $^{14}CO_2$. We are using results from these studies to improve models of forest C cycling and sequestration.

RELATED PUBLICATION

Enriched Background Isotope Study (EBIS) Workshop Report, January 2003; www.esd.ornl.gov/programs/WBW/EBISwkshp2003.htm.

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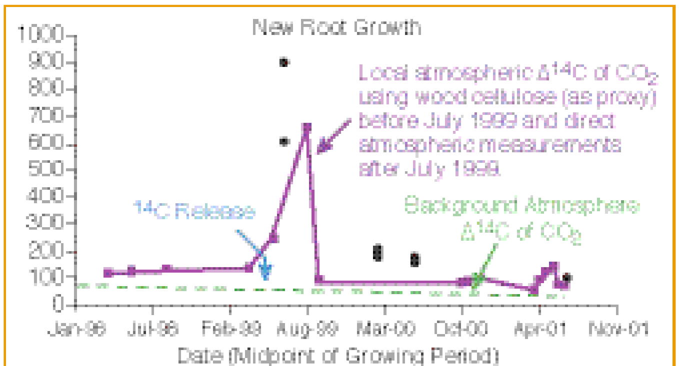

Figure 1. The change in $\Delta^{14}C$ of new root growth (black circles) over time at Walker Branch, Oak Ridge, TN. The purple line shows atmospheric $^{14}CO_2$ at Oak Ridge, with the major ^{14}C release in 1999, based on wood cellulose before July 1999 and direct atmospheric measurements after July 1999. The dashed green line is background atmospheric $\Delta^{14}CO_2$.